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Limits on the Masses of Supersymmetric Particles from 1.8 TeV p $\bar{p}$ Collisions *

The CDF Collaboration

presented by

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Abstract

Preliminary analysis of p $\overline{\text{p}}$ collision events at $\sqrt{s}$ = 1.8 TeV using events with large missing transverse energy and on two (four) jets in a minimal SUSY model places new limits on the masses of squarks (gluinos). The data sample (4 pb^{-1}) was taken in 1988-89 and is approximately 160 times as large as the data sample from our earlier 1987 run (25 nb^{-1}).

Introduction

Supersymmetry (SUSY) is a symmetry that links fermions and bosons. In this theory the fundamental fermions have supersymmetric partners. In particular the quark, gluon and photon have supersymmetric partners the squark ($\tilde{q}$), gluino ($\tilde{g}$) and photino ($\tilde{\gamma}$). We assume a rigorous conservation of R-parity, which implies that supersymmetric particles are pair-produced. In our minimal model we assume thaat all 6 flavors of squarks are degenerate in mass. We further assume that the photino is the lightest SUSY particle. The photino is also stable and does not deposit energy in the detector. Indeed one of the most important signature of new physics is the appearence of large missing transverse energy ($\not{E}_T$). The dominant Sparticle production and decay modes depend on the relative masses

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of the squark and the gluino. The case $m_{\tilde{q}} < m_{\tilde{g}}$ yields two jets, and the case $m_{\tilde{g}} < m_{\tilde{q}}$ yields four jets. We note that the final states are always composed of normal quarks and gluons and photinos.

In 1987 CDF (Collider Detector at Fermilab) searched for SUSY events in a sample of 25.3 nb^{-1} of integrated luminosity. The results were at the 90% C. L., $m_{\tilde{q}} > 74$ GeV and $m_{\tilde{g}} > 73$ GeV.[1] The present analysis is on the data (4.05 ± 0.28 pb^{-1}) taken during the 1988-1989 run. The data set for this analysis was 200000 events triggered by a $\not{E}_T$ trigger. Also required was a coincidence in forward-backward scintillation counters which signaled a p $\bar{p}$ interaction.

Data were filtered by the following requirements

(1) Missing E_T ($\not{E}_T$) is the vector sum of the transverse projections of energy deposition in all the calorimetry cells. The magnitude of the missing E_T was required to be greater than 40 GeV.

(2) Calorimetry energies were first clustered with a nearest-neighbor algorithm, and clusters separated by $R=[(\delta\eta^2) + (\delta\phi^2)]^{0.5} \leq 0.7$ were combined. The highest E_T cluster was required to be central ($|\eta| < 1.0$), and to have $E_T \geq 15$ GeV, charged fraction > 0.2, and $0.1 <$ electromagnetic fraction (EMF) < 0.9. The second jet was required to have $E_T \geq 15$ GeV, $|\eta| < 3.5$ and $0.1 < \text{EMF} < 0.9$.

(3) The significance of the E_T of an event was characterized by the quantity $S=\not{E}_T/\sqrt{E'_T}$, where E'_T is E_T summed over the central and plug calorimeters. To reject $\not{E}_T$ events due to calorimetry measurement fluctuations, we required $S > 2.4$.

(4) An important source of background events with large $\not{E}_T$ was two-jet events where the energy of one of the jets was mismeasured. Any event with a cluster of $E_T \geq 5$ GeV

within $\pm$ 30 ° in ϕ from the back-to-back direction of the highest E_T cluster was removed.

(5) We tried to remove three-jet events, where the $\not{E}_T$ is caused by the mismeasurement of the energy of one of the jets. For such events, the $\not{E}_T$ direction is approximately parallel to a jet direction. Thus all events with $| \phi_{jet} - \phi_{\not{E}_T} | < 30°$ were removed.

(6) All events with electron candidates with $E_T > 15$ GeV were removed.

(7) All events with muon candidates with $P_T > 15$ GeV/c were removed.

(8) All events with z vertex positon more than 60 cm from the center of the detector were removed.

(9) All events with multiple vertices were removed, as the $\not{E}_T$ is not well-defined for these events.

(10) A few more events were removed after being identified as cosmic ray (1 event), beam-gas (2 events), readout problems (2 events), and electronic noise (3 events).

The final sample consisted of 98 events.

Standard Model backgrounds

To understand whether the set of 98 events is consistent with standard model background, we studied several sources.

(1) W $\rightarrow$ e ν jet(s)

We will find W plus $\geq$ 2 jet events in our sample, if the electron has low Pt, or is lost in a detector crack, or is non-isolated. A W plus one jet event may be in our sample if the elecron is misidentifed as a jet. From a visual scan of the 98 events we found five W $\rightarrow$ e ν events. From a knowledge of the electron efficiency and the size of the detector cracks, we estimate that there are 6.4 such events in the sample, including the observed 5.

(2) W $\rightarrow$ μ ν jets

We will find W plus $\geq$ 2 jet events in our sample, if the muon is outside our detector coverage, or is not detected. As the muon distribution from W decay is the same as that of the electrons from W decay, we can simulate W $\rightarrow \mu\ \nu$ by removing the energy which the electron deposits in the calorimeters from the W $\rightarrow$ e ν events. We find 19 events which pass all the cuts. Based on this number and the efficiencies (for the electron cuts, the missing E_T trigger, the cracks region,....) we estimate that there are 16.6 such events in the sample.

(3) W $\rightarrow \tau\ \nu$ jets

We will find W plus $\geq$ 2 jet events in our sample, if the tau decays to an electron which has a low Pt or is lost in a crack. Similarily if the tau decays to a muon which is outside our coverage or not detected. We will also find the event in our sample if the tau decays to hadrons. We can also find W plus 1 or more jet events in our sample when an energetic tau decays to hadrons which are seen as a jet. Again as the tau distribution from W decay is the same as the electron distribution from W decay, we can simulate the tau sample by taking the electron sample and replacing the electron by a tau. The tau then decays and the standard cuts are applied. We find 15 events passing our cuts. After correcting for the efficiencies this implies that there are 30.7 events in our sample. Aa a check we scanned the 98 events and found 9 taus where the tau has decayed to a hadron. A simulation of our scan criteria tells us we should expect to see 11 events.

(4) Z $\rightarrow \nu\ \overline{\nu}$ jets

We expect to find these events in our sample. Again one can estimate this sample by taking the Z $\rightarrow$ e e sample and replacing the electrons with neutrinos. Because we have a much larger W $\rightarrow$ e ν sample the W sample was used to estimated this background. This is the largest background and is estimated to be 32.7 events.

(5) QCD events

The principal source is 3 jet events where one of the jets is lost or mismeasured. We estimate the background from QCD processes and b quark decays to be 4 $\pm$ 4.

In summary we estimate from our own data that there are 86.4 $\pm$ 14.1 (stat) $\pm$ 11.6(sys) events from intermediate Boson decays, and 4 $\pm$ 4 from QCD.

SUSY simulation

We have estimated the expected number of SUSY events for different combinations of ($m_{\tilde{q}}$,$m_{\tilde{g}}$) in the mass range 140- 500 GeV using ISAJET.[2] The systematic uncertainty in our expected SUSY events comes from the following factors.

(1) The uncertainty in our integrated luminosity is 6.8%.

(2) The uncertainty in the choice of Q^2 scale in ISAJET is 15%.

(3) The uncertainty in the overall calorimetry energy scale is 1%.

(4) The uncertainty in the $\not{E}_T$ trigger efficiency is 4%.

(5) We use EHLQ1 structure functions[3], which have the lowest predicted SUSY cross sections. No systematic uncertainty is included for structure function uncertainty.

The total systematic uncertainty is 17%, adding the various contributions in quadrature.

SUSY particle mass limits

We have seen that the number of observed events (98) is consistent with that expected from the standard model plus QCD (90 $\pm$ 15(stat) $\pm$ 12 (sys)). To actually set the limits we consider 2 cases:

(1) $m_{\tilde{q}} < m_{\tilde{g}}$

We have 3 events with $\not{E}_T > 100$ GeV and 2 or more jets. We estimate the background is 1.3 events with a systematic uncertainty of 8% and a statistical uncertainty of 100%, we find the 90% C.L. is 6.0 events.

(2) $m_{\tilde{q}} > m_{\tilde{g}}$

We have 2 events with $\not\!E_T > 40$ GeV and 4 or more jets. We estimate the background is 1.3 events with a systematic uncertainty of 8% and a statistical uncertainty of 100%, we find the 90% C.L. is 4.8 events. The preliminary results are shown in Fig. 1.[4,5]

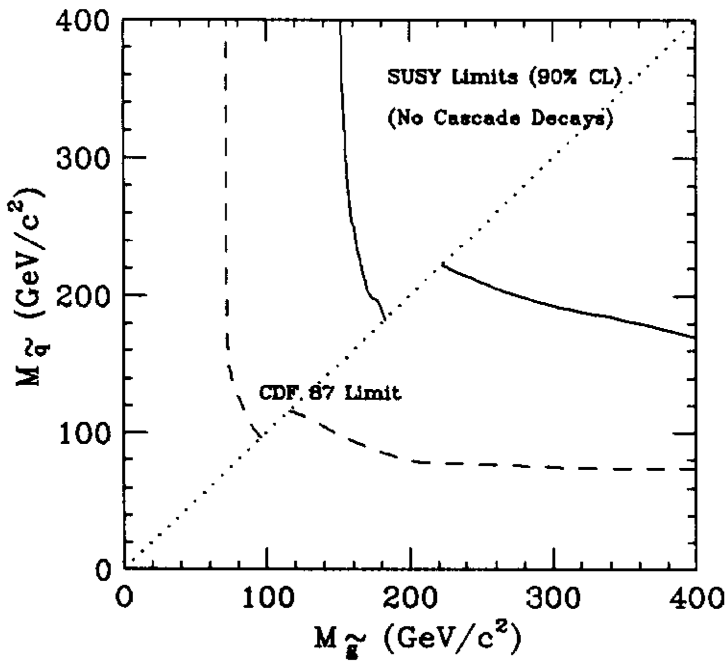

Figure 1: The 90% C.L. excluded region in the ($m_{\tilde{g}}$,$m_{\tilde{q}}$) plane.

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